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The Stellar Magnitude Scales of the Astrographic Catalogue. Fourteenth Note: The Tacubaya Magnitudes (−16°) *and the Cape Magnitudes* (−43°).

By H. H. Turner, D.Sc., F.R.S., Savilian Professor.

1. In the eleventh note (*M.N.*, 78, 54) the promise of another Tacubaya zone (−16°) was announced; and in the twelfth note (*M.N.*, 78, 589) it is stated that another Cape zone (−43°) was being counted. The Tacubaya zone was received from Sen. Gallo a few weeks since, the counts of the Cape zone were completed some months ago, and it is the principal object of this note to add this material to the steadily accumulating information about the southern hemisphere. But in view of the gatherings for scientific discussion among the Allies, and the prospects of a resumption of co-ordinated work on the Astrographic Catalogue, a few words may be added on the primary purpose of these investigations.

2. At the last meeting of the Comité Permanent in April 1909 it was resolved to initiate considerable investigations for the unification of (*a*) the places, (*b*) the magnitudes of the stars measured. I have grave doubts (which have been put forward on several occasions) as to the advisability of *either* project in the form in which it was left by the Committee. At the moment project (*a*) does not concern us. The main lines of project (*b*) may be thus described: Assuming that the magnitude scale is *uniform for each observatory*, but with errors special to each, let us investigate these special errors by photographs of sample regions on the same plate as the region of the Pole.

3. Now, the main purpose of the present series of papers is to test the fundamental assumption here made. If the scale at each observatory is *not* uniform, the work based on this assumption may be in large part wasted. My contention is that we can, with comparatively little labour (which is in no case wasted, since the work involved must in any case be carried out at some time), exhibit the consequences of this assumption, by simply counting the stars assigned by any observatory to the same magnitude, whatever that magnitude may be. If, on the one hand, it turns out that the scale *is* satisfactorily uniform, then these counts will in any case be useful to tell us how many stars of a given magnitude there are in that part of the sky. But, on the other hand, they may arrest scrutiny earlier and thus save waste, for they may show that the scales are not uniform enough to allow of systematic correction.

4. To take an illustration from another department of astronomy. It is advisable to determine the division errors of a circle, and although the work is serious—"six weeks' convict labour" it has been called by the late Professor Lewis Boss—the labour is well expended, since the division errors remain constant, surviving even the transportation of the instrument over long distances, as Boss himself proved by repeating the laborious investigation

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after transportation. But suppose the division errors had *not* been stable, suppose that they were so unstable that observations of the same star were apt to differ by several seconds on different nights, it would then have been sheer waste of time and labour to investigate the errors unless the instability could be traced to its source and completely corrected. My assertion is that the division errors of the photometric scales of the various observatories are rendered unstable (by personality of the measurers and other less obvious causes) to an extent which renders the proposed investigation waste labour until the causes of instability have been first investigated and if possible removed.

5. As another piece of evidence in support of this assertion (many have already been given) let us consider the measures of zone −43° (given below) at the Cape Observatory under two broad classifications:—

(*α*) All the bright stars for which measures are recorded between 1·99 and 1·00. (There are stars brighter than these for which the measures are 2·00 and more, but we exclude these for the moment.)

(*β*) All those stars with *measures* less than 1·00. The lower limit is assigned by passing from measures to estimates. We are not now raising any question about this limit except that of its constancy throughout the zone −43°, nor making any assumption beyond that tacitly implied in the publication of such results by an observatory with the reputation of the Cape, viz. that a volume of results is intended to be on a uniform plan unless some special warning is issued with it.

6. Let us, then, compare the numbers of such stars from 0^h to 17^h and from 18^h to 23^h; we find them to be as follows:—

	(α).	(β).	$\log \alpha - \log \beta$.
0^h–17^h	11045	8466	+0·115
18^h–23^h	2978	4233	−0·154

The difference in $\log \alpha - \log \beta$ is 0·269, corresponding to more than half a magnitude. The consistency of the difference is shown in Table I. by giving $\log \alpha - \log \beta$ for each hour of R.A.

TABLE I.

Cape −43°: *log α–log β for each hour of R.A. in units of* 0·01.

h		h		h		h	
0	+11	6	+ 8	12	+ 6	18	−14
1	+10	7	+11	13	+17	19	−22
2	+22	8	+22	14	+26	20	−16
3	+17	9	+ 2	15	+17	21	−12
4	+24	10	+ 7	16	+17	22	− 8
5	+10	11	− 5	17	+17	23	−11

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7. As far as 17^h there is but one negative value (at 11^h); after it there is no positive value. The probable error of an hourly difference is about ± 4 (in the adopted unit of 0·01), so that the abrupt change at 17^h–18^h is almost certainly real. A glance at the table in the introduction to the volume suggests that it is probably a case of personality, the plates after 17^h being chiefly measured by ES and NM, initials which scarcely occur at all before this point.

8. But it is undesirable to pursue the matter further here, since personal differences can only be studied to the best purpose at the observatory itself, where all the circumstances are fully recorded and understood. The point to which attention is here emphatically drawn is, that an elaborate scheme for testing individual plates in detail, such as that projected at the last meeting in 1909, though it may give useful information about those particular plates, is foredoomed to failure as an examination of the whole material, unless the homogeneity of that material is first ascertained and corrections obtained for discordances when found. That such discordances are the rule rather than the exception it has been the main purpose of these papers to demonstrate, though other investigations have arisen incidentally.

9. We may now give the main counts for Cape −43°; those for −41° have been given already (*M.N.*, **75**, 59). As regards −42°, the harmonic analysis was given (*M.N.*, **78**, 589) but not the actual counts, which may as well now be given alongside those of −43° in Table II. The heading 2 includes all stars from 2·00 to 2·99; it will be clear that they can easily be counted by concentrating attention on the integer. The heading [0] is limited in one direction by 0·99, but in the other by *about* 0·6, after which measures are replaced by estimates. Attention has already been called to the uncertainties of the lower limit.

10. In Table III. is given the harmonic analysis of the −43° results in the same form as Table XI. on p. 589 of *M.N.*, **78**.

Table

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TABLE II.

Counts of Stars in Cape Zones – 42° *and* – 43°.

	−42°					−43°				
R.A.	3	2	1	[0]	–	3	2	1	[0]	–
0h	4	28	186	172	410	14	30	197	153	531
1	12	26	242	278	377	14	34	182	144	577
2	9	23	253	156	637	8	25	186	113	565
3	5	28	293	253	621	4	29	280	192	849
4	16	51	382	413	849	9	33	286	167	1057
5	22	76	639	608	1402	10	52	529	417	1654
6	28	88	681	754	2105	29	77	664	547	2078
7	30	130	1032	874	2745	38	110	906	711	3553
8	46	155	1370	1166	3198	58	188	1736	1039	3819
9	12	68	1159	571	2174	19	103	1030	985	3038
10	17	60	1036	741	2625	27	72	659	559	2283
11	19	53	497	282	1961	24	66	536	606	1992
12	10	34	335	258	1252	6	22	313	277	1237
13	27	54	551	328	1807	16	44	570	386	2312
14	9	35	540	380	2192	14	51	649	357	2200
15	10	77	672	619	3440	19	85	764	518	2610
16	36	61	688	942	3367	15	58	517	346	2112
17	15	90	1169	1540	7066	15	110	1041	949	4570
18	19	116	1143	2331	8566	32	104	1193	1648	3736
19	10	60	645	580	3006	9	58	622	1019	1799
20	17	35	411	372	1478	16	55	434	638	1125
21	8	24	324	280	1132	9	38	319	420	641
22	9	26	252	271	488	8	33	210	249	336
23	11	22	187	156	486	11	37	200	259	447
Total	401	1420	14687	14325	53384	424	1514	14023	12699	45121

There are some conspicuous differences between the two zones, especially in the last columns. Compare these two columns, for instance, at 4^h and 18^h. At present we have no resource but to treat such differences as accidental.

TABLE III.

Harmonic Analysis of Residuals for Zone – 43°.

d.	log No.	sin θ.	cos θ.	sin 2θ.	cos 2θ.	sin 3θ.	cos 3θ.	sin 4θ.	cos 4θ.
3·00	9·98	+·054	+·006	−·100	−·031	+·037	+·131	+·101	+·01
2·00	0·71	+·031	+·056	−·105	−·082	+·033	+·073	+·051	+·00
1·00	1·67	+·012	+·026	−·082	−·107	+·006	+·005	+·043	+·00
[0·00]	1·94	−·034	+·063	−·142	−·095	+·008	−·025	+·044	+·03
All	2·38	−·007	+·015	−·057	−·107	+·027	−·025	+·053	+·03
Diff.	1·94	−·084	−·004	−·012	−·013	−·004	−·128	+·003	+·04
	1·00	−·043	−·002	−·006	−·007	−·002	−·066	+·002	+·02

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The penultimate line is the excess of the sums of those for [0·00] and "All" over 2·00 and 1·00, and on dividing by 1·94 we get the final line.

For the first harmonic $R_0 = -·043$, $\theta_0 = 87°$.

[On p. 589, *loc. cit.*, the − sign of R_0 for zone −42° has unfortunately been omitted in the text, though it is given correctly in the little table just below.] The accordance with other zones is undoubtedly affected by the systematic difference between the portions 18^h–23^h and 0^h–17^h, to which attention is called above; but the interference has affected the coefficient R_0 rather than the phase θ_0, which is in good accordance with those of +38°, +41°, and +42°, the four values being 91°, 77°, 106°, and 87°. These four zones give a good determination in this neighbourhood, as shown below; but before tabulating their means, let us first turn to the Tacubaya zone −16°, which also completes a set of four zones, two from Tacubaya and two from Hyderabad.

11. The counts, as kindly supplied by the Director of the Tacubaya Observatory, are given in Table IV. They were treated in the manner fully explained for zone −15° in *M.N.*, **78**, 62, etc., and the harmonic analysis is given in Table V.

TABLE IV.

Tacubaya Zone −16°.

Hour.	No. Plates.	Brt.	8·5.	9·0.	9·5.	10·0.	10·5.	11·0.	11·5.
0	8	49	41	59	208	279	272	146	119
1	7	53	37	45	113	195	150	233	78
2	8	53	38	54	128	220	202	123	216
3	7	46	41	57	116	149	96	221	81
4	8	63	48	71	166	131	137	204	193
5	7	69	71	96	236	299	326	561	331
6	8	70	61	138	327	441	682	1428	1176
7	7	68	66	176	332	602	2013	3422	2342
8	8	91	107	143	314	671	1041	1764	1813
9	7	59	44	122	74	267	654	598	718
10	8	51	53	80	136	232	412	450	416
11	7	36	41	38	69	152	140	439	412
12	8	31	33	73	128	204	342	447	263
13	7	32	34	68	98	104	340	342	155
14	8	32	38	57	140	159	237	585	646
15	7	32	26	61	115	258	240	323	261
16	8	39	27	35	108	255	441	484	159
17	7	50	41	177	232	464	1071	806	181
18	8	93	66	196	509	478	1716	2641	1809
19	7	44	89	172	289	594	1382	934	803
20	8	64	112	129	251	564	838	1237	981
21	7	33	43	78	173	268	410	621	543
22	8	45	51	84	127	225	313	280	316
23	7	50	30	65	121	221	215	197	231
Sums		1253	1238	2274	4510	7432	13670	18486	14243

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TABLE V.

Tacubaya – 16°.

Harmonic Analysis of the Residuals formed from Table IV.

Tac.	log N_0.	sin θ.	cos θ.	sin 2θ.	cos 2θ.	sin 3θ.	cos 3θ.	sin 4θ.	cos 4θ.
8·0	0·51	+·105	+·113	+·006	+·065	+·037	–·015	+·006	–·008
9·0	1·13	+·047	+·105	–·073	+·061	+·002	–·059	+·038	–·012
10·0	1·71	+·016	+·143	–·073	+·062	–·004	–·004	+·055	+·005
11·0	2·15	–·023	+·042	–·149	+·017	–·008	+·013	+·101	·000
All	2·26	–·015	+·026	–·171	+·028	–·021	+·011	+·102	–·008
	2·77	–·190	–·150	–·253	–·081	–·068	+·098	+·159	+·012
	1·00	–·069	–·054	–·091	–·029	–·024	+·035	+·057	+·004

The penultimate row is obtained by subtracting the sum of the first two from that of the last two, and then dividing by 2·77 we get the final row.

For the first harmonic $R_0 = -·087_0$, $\theta_0 = 52°$. The values of θ_0 obtained for zones –15°, –16°, –17°, –18° are thus 19°, 52°, 35°, 316°.

12. We may now collect the results from –15° to –43°, which fall into three groups, of which means are taken. The terminal groups are compact, the middle group could be improved in this respect.

TABLE VI.

Collected Coefficients for the Harmonics, corresponding to change of 1·00 *in log* N_0.

Zone.	sin θ_0.	cos θ_0.	sin $2\theta_0$.	cos $2\theta_0$.	sin $3\theta_0$.	cos $3\theta_0$.	sin $4\theta_0$.	cos $4\theta_0$.
–15	–·053	–·149	–·139	–·105	+·020	+·092	+·142	–·027
–16	–·069	–·054	–·091	–·029	–·024	+·035	+·057	+·004
–17	–·074	–·104	–·042	–·001	+·096	–·076	+·046	–·053
–18	+·047	–·049	–·129	–·043	+·065	+·019	+·088	+·007
Mean	–·037	–·089	–·100	–·045	+·039	+·018	+·083	–·017
–25	–·024	+·068	–·014	+·027	–·007	–·017	+·022	–·042
–32	–·043	·000	–·008	–·025	–·011	–·013	+·013	–·032
–34	–·061	+·001	–·002	+·063	–·015	+·014	+·057	–·004
Mean	–·043	+·023	–·008	+·022	–·011	–·005	+·031	–·026
–38	–·127	+·003	+·048	–·037	–·038	–·015	+·053	+·010
–41	–·115	–·027	+·001	–·016	+·005	–·028	+·010	+·001
–42	–·088	+·026	+·001	–·030	+·036	–·006	–·022	+·012
–43	–·043	–·002	–·006	–·007	–·002	–·066	+·002	+·023
Mean	–·094	·000	+·011	–·022	·000	–·029	+·011	+·012

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13. Subtracting the means as indicated from the constituents above them, and taking numerical means of the residuals in each harmonic (treating $\sin\theta$ and $\cos\theta$ together), we get for the mean residual ±·028, ±·023, ±·027, ±·021. These means include any real differences between the zones.

14. The large value ±·028 for the first harmonic is principally due to the large discordances of zone −18° and −43° in $\sin\theta_0$, and of zone −25° in $\cos\theta_0$. The change in $\cos\theta_0$ between −18° and −25° is marked. It seems scarcely possible to admit accidental errors which would reconcile the large and consistent negative value from −15° to −18° with the small positive value which persists from −25° to −43°. It is perhaps worth remarking that two well-separated observatories (Tacubaya and Hyderabad) are concerned in the former group, and three (Cordoba, Perth, and the Cape) in the latter.

15. Is it conceivable that the change in site from the northern hemisphere to the southern can be responsible for so large a systematic *differential* effect? For it must be remembered that the coefficients tabulated are the *differences* of log N for bright and faint stars. If this is really the cause, the information is almost as important as if the source lay in the stars themselves, for there must be some hitherto unsuspected instrumental error of a kind which is liable to affect all our work seriously.

16. This possibility being open, it seems desirable to test it by photographing the same zone at a northern and a southern observatory. Thus if zone −22°, which is being photographed at Santiago and measured at Oxford, were also photographed at Hyderabad, the comparison should go far to settle the question raised.

Note on a Curious Instance of Opposite Proper Motions.

By Ethel F. Bellamy.

(*Communicated by Professor H. H. Turner.*)

In forming ledgers of the plates in the Vatican zones of the *Astrographic Catalogue*, I came across a curious instance of two stars, Helsingfors A.G.C. 13277 and 13278, within two minutes of arc in the heavens, and with opposite proper motions. They occur on two plates taken twelve years apart, and with different centres, as below :—

Centre of Plate.		Date of Exposure.	H 13277.		H 13278.	
R.A.	Dec.		Δx.	Δy.	Δx.	Δy.
h m	°					
22 24	+60	1901·789	+·007	−·001	−·010	·000
22 32	+61	1913·846	+·012	−·001	−·017	+·001